A brief historical review shows how human activities were involved in the ecology of malaria, and how malaria was spread to much of the United States. Furthermore, the relation between changing habits of man and the retreat of the disease is discussed. Finally, the active attack against anophelines is put in proper perspective, and the place of eradication is clearly delineated.

MALARIA ERADICATION IN THE UNITED STATES

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MALARIA was always an unstable disease in the United States, seasonal in occurrence, characterized by epidemics, and with cyclical variations over a period of years. Yet before the tide turned and a great recession set in near the end of the 19th century, it spread to nearly all parts of the country, finally centering in the southeastern states where planned malaria control became necessary. In retrospect the causes of this great excursion and contraction are easily seen if one bears in mind the fixed habits of the two mosquitoes involved and the effect upon them of the changing habits of man.

Malaria is transmitted in the East by Anopheles quadrimaculatus, a poor vector. Although it readily enters houses and feeds on man it prefers animals; less than 5 per cent contain human blood. Precipitin tests[1] have shown that it had fed on either man or animals whether captured in the house or stable. There is no evidence that once having fed on man it has any predilection to return to him for subsequent feedings, and but few do.

Anopheles quadrimaculatus is an impounded water mosquito breeding among the flotage of man-made or natural ponds and lakes where the water is quiet, sunlit, and slightly alkaline. It avoids the acid waters of densely treed swamps until lumbering operations let in the sunlight, soon followed by algae and other water vegetation which destroy acidity and provide flotage, protection, and food. After a few years, ponds reach a stage of biological equilibrium when the stranding of flotage and increment of predators greatly reduce larval density. This is usually reflected in a reduction in malaria rates, for the mosquito's infective flight range is short; not over a mile when its density is high, and often reduced by lower densities to less than a quarter of a mile. Increase in the number of barnyard animals interposes an additional barrier to transmission.

In the West the mosquito is of a different species, Anopheles freeborni, but in its western habitat it has just as sharply defined breeding characteristics which makes its relation to malaria as easy to follow as in the case of A. quadrimaculatus. It requires constantly refreshed water. Herms used to call it a seepage-leakage anopheline.[2] It likes to breed in the leakages and seepages from irrigation canals, in seepages wherever the water table outcrops or where irrigated fields are undrained. It

bred prolifically in the leakage pools from hastily dug hill-side trenches into which streams were diverted in earlier days to allow gold panning in their beds; and malaria epidemics promptly followed. In the rice areas it avoids those fields underlaid with hardpan where the water is stagnant and unrefreshed, and breeds only in the seepage ditches at the base of the dikes; but it breeds abundantly in the fields with gravelly bottoms where irrigation gates are left slightly open to replace water sinking away.

Typical is the history of impoundments, new ones, in New England which clearly shows their close relationship to malaria. As the country became settled innumerable small mills sprang up everywhere. Sawmills vital to the shipbuilding and timber exporting industries soon became general throughout the country. At first at the fall line they followed settlement up the streams, and as one historian[3] put it "side by side with the fulling-mills . . . were built mills for grinding corn. Everywhere the traveler in New England stumbled upon them beside the picturesque stream, whose waters had been harnessed to the wheel. . . ." And malaria followed, only to recede as ponds were stabilized or destroyed. Later, as Holmes[4] has recounted, malaria had a resurgence as towns and the larger villages impounded water supplies at their borders. Still later, when populations grew up to these reservoirs, they were enlarged by moderate elevation of the dams flooding the land vegetation on the banks and providing new flotage areas. Malaria epidemics then occurred in the portion of each town adjacent to the reservoir. The last notable recrudescence occurred at the turn of the century when new coastal roads partially dammed the outlets of streams by their fills and short bridges.

After each impoundment, the passage of a few years brought the ponds into a state of biological equilibrium with consequent reduction of anopheline density, and malaria disappeared. As for mill ponds, sewage and factory effluent pollution finally eliminated most of them as anopheline breeding areas.

With some differences the same general factors were operating in the southeastern states and in the Mississippi Valley. Shallow waters were more abundant, and there were many more swamps to be lumbered, while the human propensity to impound small (and later large hydroelectric) ponds was just as operative. The equable climate was conducive to less well built rural houses and the warmer climate and longer summers made the transmission of malaria easier. Rice fields with their many fresh water "reserves" added to the extent and severity of malaria.

Resettlement of returning Civil War veterans carried the disease into the upper Mississippi Valley to the shores of the Great Lakes. Selective hardwood lumbering in the overflow areas of streams with consequent innumerable sunlit pools caused severe epidemics.[5] As the value of agricultural lands rose, the great drainage districts of the region came into being, and in the last part of the 19th century malaria started its southern retreat.

With abandonment of the one crop system and introduction of industries, the economic development of the South began to rise at an accelerated pace. Steadily increasing animal husbandry created another obstacle to transmission by animal deviation, for "quads" prefer to feed on cattle.

In the second decade of the 20th century active control of malaria commenced. Through stimulation and aid from the Public Health Service, soon joined by the Rockefeller Foundation, antimalaria works were inaugurated in a few southern towns and villages in each of eight southern states, and an

educational campaign began. A campaign which started in the schools (1913) was taken up and pushed by the state health departments and continued for over 30 years, educating a whole generation in the cause and control of malaria and well conditioning them to support programs for controlling the disease.

State health departments grew rapidly in size and importance and each southern one developed an effective division of malaria control. County health departments advanced in number until many states were completely covered and malaria was driven away from the towns and larger villages. Better roads and motor transportation began the rural migration to malaria-free communities. Development of wind-blown Paris green encouraged antilarval programs in rural areas, and the county-wide screening and mosquito-proofing programs of the lower Mississippi Valley were very effective rural control methods. Perhaps even more effective was the general use of Flit and other household insecticides.

All of this was aided materially by the expanding anopheline control works along the shores of hydroelectric and navigation lakes, notably the enormous operations of the Tennessee Valley Authority, which destroyed malaria throughout the entire watershed of the Tennessee River. Malaria control at impounded waters became popular and the lesson sank home when new and uncared for impoundments in areas recently freed from the disease produced surprising epidemics,[6] although these were small and local and none persisted into the subsequent year.

Large mosquito control districts were organized in the West, often more for the comfort of pest control than for malaria reduction, but they played a significant part in reducing malaria rates. Also, it is true that the reduction of western malaria, particularly in California, has accompanied the rising price of irrigation water. As its value increased, canals were better cared for even to lining them with concrete or putting them underground.

Widespread government antimalaria programs commenced with the utilization of laborers on relief during the depression of the 1930's under the direction of the Public Health Service working through state health departments. Over 30,000 miles of ditches were dug and thousands of tons of Paris green were spread as a larvicide. At that time the winter rate of infection (winter of 1933) was 5.8 per cent[7] among 129,000 southern school children. The last cyclic upswing occurred from 1934 to 1936. The predicted rise of 1941-1942 did not occur. Probably the extensive relief work had prevented it.

The relief program was quickly followed by the Malaria Control in War Areas (MCWA) campaign which covered a large part of the South. An index taken from 120,000 children within the work area showed only 0.21 per cent positive in 1943, and by the autumn of 1944 only 0.11 per cent[8] positive.

Outside the war areas malaria still persisted, and in 1945 the work was extended to include all counties where records indicated that the disease represented a continuing problem. By this time the usual malariometric methods had proved to be ineffectual. Reliance had to be placed upon estimates based on five-year reports of mortalities. The Extended Malaria Control Program was carried on in 315 counties in 13 states.[9] This program involved the use of DDT as a residual spray in two and a half million houses and continued for two years.

In 1947 the Malaria Eradication Program commenced with full cooperation of the 13 affected states. Supervision was given through operational offices established in each state. The govern-

ment supplied technical personnel, transport, equipment, and materials. The states and localities provided all labor.

Two hundred milligrams of DDT to the square foot were sprayed on the interior walls twice a year. Later this was reduced to one annual application. This was believed to have stopped transmission because observations of afternoon roosting mosquitoes within houses over a five-year period (1945-1949)[10] showed that virtually all treated houses were free from A. quadrimaculatus for five months or more, whereas they were found in 16 per cent of comparable but unsprayed houses.

It seems probable, almost to the point of certainty, that transmission of malaria was terminated somewhere between 1945 and 1947. In the subsequent three years the reservoir of plasmodia drained out of the population. On the assumption that transmission had indeed been terminated, a system of surveillance was inaugurated. This depended largely on case reporting, and a great effort was made to improve diagnosis by setting up refresher courses for technicians and health department personnel and insisting that cases be reported by name and confirmed by blood slide examination. One state even went so far as to make a cash donation to each physician if the slide was found positive in the laboratory. The outlay proved very small.

Epidemiologists, entomologists, nurses, and engineers were supplied to many states supplementing their epidemiological facilities to find unreported cases, verify diagnoses, appraise cases as to source, and take remedial measures in each confirmed case. This program was soon taken over by the states, with some assistance from the Communicable Disease Center, and is still in operation.

From 1943 to 1946 there was a slight decline in the downward curve of reported cases, but this was due to relapses in returned overseas veterans. Soon, newly discovered antimalaria drugs reduced this danger. In the unsprayed states the morbidity curve had practically reached the zero point by 1949, and in the 13 sprayed ones was under 10 per 100,000.[9] From 1949 to 1952 there were reported some 19,000 cases of which approximately 5,000 were appraised. Nearly 3,000 were positive but only 62 were of local origin.[10] Examination of the evidence leads one to suspect that these cases were derived from infected servicemen from Korea, though four of them were from unknown sources.

Recent surveillance reports from CDC, excluding blood transfusion cases, show that in 1956 there were 238 cases reported, but only 93 were confirmed. Most of these were of foreign origin, only 10 being classed as primary indigenous. By 1958 only 94 were reported and 61 confirmed, of which only 3 were primary indigenous. In 1959 reports fell to 66 with 33 confirmed and 4 indigenous. In 1960 there were 63 reported with 47 confirmed, but only 2 classed as primary indigenous. One wonders whether those listed as "primary indigenous" might not be classed under a heading of "source not found?"

Summary

This brief history has shown how the habits of man encouraged production of anophelines and spread malaria to much of the United States. Also, how the changing habits of man caused its retreat to the southern states. But, in the South, an active attack against anophelines had to be added. Years of control works were steadily reducing malaria and would doubtless have resulted in eliminating the disease, but its eventual termination date was not readily foreseeable.

New infections kept the human reser-

voir of malaria too refreshed for it to die out through attrition. A period of time without transmission was required to permit this reservoir to drain away. This period of time was provided by the final attack, the malaria eradication campaign, and the human reservoir of infection was drained. Once free of malaria, the population easily withstood the impact of thousands of imported cases, endemicity did not recur. I believe that the rare transmission taking place today is from imported cases and will cease when global eradication has been achieved.

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CDC Announces Course for Veterinarians

A course in Epidemiology for Veterinarians will be offered at the Communicable Disease Center in Atlanta, February 25-March 1, 1963. Registration will be open to doctors of veterinary medicine who are engaged in public health, private practice, regulatory activities, instruction or research. In addition to lecture-discussion sessions there will be group participation through the utilization of group solution of epidemiologic problems, seminar-type presentations, and panel discussions. Throughout the sessions, an appreciation of epidemiology as a tool in disease prevention and control is stressed.

Enrollment is limited to approximately 50 persons. Applications from Dr. Norman R. Tufts, Assistant Chief, Health Services Training Section, Training Branch, Communicable Disease Center, Atlanta 22, Ga.